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RESEARCH ARTICLE
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Importance of Rainwater Harvesting as an Alternative Water Resource and its Potential in Türkiye

Alternatif Bir Su Kaynağı Olarak Yağmur Suyu Hasadının Önemi ve Türkiye'deki Potansiyeli

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ABSTRACT

Rainwater harvesting (RWH) that has many application areas extending from indoor uses to outdoor practices been accepted as an alternative water resource especially by developing countries experiencing water scarcity. In this article, general features and usages of RWH are included coupled with evaluations. RWH potential in Türkiye was calculated separately for 81 provinces. Using the average precipitation data between 1991-2020, the amount of rainwater that can be collected from the roofs was calculated based on a typical roof area of 100 m^2. Two different calculations were made based on this main data. According to the first calculation, the water needs of one person for more than 365 days can be met with annual RWH in 22 provinces, while in 12 provinces, the water needs of less than 7 months in 1 year can be met. In other provinces, this period varies between 200-365 days. The second calculation determined how much water can be saved from the annual water need if this amount is allocated for the use of a family of 4 people. The results indicate that the savings varies between 9.23-80.19%. While this rate is between 26-80% in 22 provinces where one person's water needs for more than 365 days can be met with the RWH collected in 1 year, in 12 provinces where the water needs of less than 7 months in 1 year can be met, this rate varies between 9.23-13.74%. This situation shows that water saving is possible even in provinces with the least rainfall.

Keywords: Rainwater harvesting, Türkiye, Water saving

ÖZET

İç mekân kullanımlarından dış mekân uygulamalarına kadar pek çok uygulama alanına sahip olan yağmur suyu hasadı (YSH), özellikle su kıtlığı yaşayan gelişmekte olan ülkeler tarafından alternatif bir su kaynağı olarak kabul edilmektedir. Bu makalede, YSH'nın genel özelliklerine ve kullanım alanlarına değerlendirmelerle birlikte yer verilmiştir. Türkiye'deki YSH potansiyeli 81 il için ayrı ayrı hesaplanmıştır. 1991-2020 yılları arasındaki ortalama yağış verileri kullanılarak, 100 m^2'lik tipik bir çatı alanı esas alınarak çatılardan toplanabilecek yağmur suyu miktarı hesaplanmıştır. Bu ana verilere dayanarak iki farklı hesaplama yapılmıştır. İlk hesaplamaya göre 22 ilde yıllık YSH ile bir kişinin 365 günden fazla su ihtiyacı karşılanabilecekken, 12 ilde ise 1 yılda 7 aydan az su ihtiyacı karşılanabilecektir. Diğer illerde bu süre 200-365 gün arasında değişmektedir. İkinci hesaplamada ise yıllık su ihtiyacından, bu miktarın 4 kişilik bir ailenin kullanımına ayrılması halinde ne kadar su tasarrufu sağlanabileceği belirlenmiştir. Sonuçlar tasarrufların %9,23-80,19 arasında değiştiğini göstermektedir. Bir kişinin 365 günden fazla su ihtiyacının 1 yılda toplanan YSH ile karşılanabildiği 22 ilde bu oran %26-80 arasında iken, 1 yılda 7 aydan az su ihtiyacının karşılanabildiği 12 ilde bu oran %9,23-13,74 arasında değişmektedir. Bu durum, en az yağış alan illerde dahi su tasarrufunun mümkün olduğunu göstermektedir.

Anahtar Kelimeler: Yağmursuyu hasadı, Türkiye, Su tasarrufu.

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INTRODUCTION

Scarcity of water resources is a growing problem all around the world. It has been reported that 2.3 billion people in the world suffer from water shortage, and 4 billion people experience serious water scarcity for at least one month of the year (UN Water, 2021). On the other hand, the World Meteorological Organization (WMO) predicts that droughts have increased by 29% since 2000 and that droughts may affect more than ¾ of the world's population by 2050 (WMO, 2021; Raimondi et. al., 2023).

As experienced within the past few decades, climate change causes changes in precipitation patterns and while the amount of precipitation increases in some regions, drought occurs in others. This situation leads to changes in freshwater availability, and while there is more water than needed in some regions and periods, it causes water scarcity in some others. Rising temperatures cause greater evaporation from rivers, lakes and other freshwater sources, causing water levels to drop and salinity to increase, making it harder to use water for human consumption

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or irrigation. Additionally, climate change is causing glaciers and snow to melt rapidly, which leads to floods in the short- term and decreased water availability in the long- term. Moreover, increasing temperatures as a result of climate change cause pollution of freshwater resources and can make water resources unsafe for human consumption. This situation worsens the intense pressure on existing water resources due to increasing population and water demand (UN Water, 2021). Managing limited water resources to build resilience against climate change and serve a growing population requires an integrated and comprehensive approach.

A region is considered as 'water stressed' when it draws 25% or more of its renewable freshwater resources. Water stress values in 5 out of 11 regions in the world are above 25%. 72% of all water withdrawals in the world are used for agricultural irrigation, 16% for domestic purposes, and 12% for industrial activities (UN-Water, 2021). Water resources management should be a holistic approach for managing water supply and water risks ensuring sufficient quantity and quality to meet water demands, including all these services, as well as energy production, water transport and navigation, recreation and the protection of sustainable ecosystems and natural well-being. This can only be achieved through sustainable water management approaches, planning and implementing the most effective and environmentally-friendly ways to manage resources and maintain equitable and affordable access to water. In general, scarcity of water resources appears to be a problem of especially developing and underdeveloped countries (Silva et al., 2015).

According to the State Hydraulic Works (DSI) reports of Türkiye, the annual amount of usable water per person was 1.652 m³ in 2006, whereas this value was calculated as 1.323 m³ in 2021. There has been a serious decrease in the annual amount of usable water per person between 2006 and 2021 (Selimoğlu and Yamaçlı, 2022). When the water situation in our country is evaluated according to the Falkenmark index (Falkenmark et al., 1989), it is seen that Türkiye will be among the countries experiencing water stress in the future (Table 1).

Table 1: Values of the Falkenmark indicator (Falkenmark et al., 1989)

Water (m³ /person /year)	**Classification**
1700 and above	No water stress
1700- 1000	Water stress
1000 – 500	Water scarcity
500 and below	Absolute water scarcity

The results obtained in a study conducted by Hakyemez (2019) in 25 river basins of Türkiye based on the Falkenmark indicator are given in Table 2. As can be seen from the data in the table, while Türkiye is under water stress, it is understood that some regions/basins are water rich, some are under water stress, but some are experiencing absolute scarcity.

Continuously providing sufficient water, especially to large cities with high populations, also requires significant amounts of other resources such as energy and infrastructure systems. Therefore, even countries with good water balance conditions between demand and available water resources are constantly evaluating alternative solutions (e.g. reduction in water consumption and identification of new sources to supply water) to balance water management (Haque et al., 2016). In this context, one of the most common and applicable alternative water resources is rainwater harvesting (RWH).

RWH is a simple method that has been used for thousands of years in drier lands around the world, especially in regions where other water sources are scarce or difficult to access. However, in the industrial era, the availability of technical means that enabled the transfer of water from remote areas through long and complex systems like the capacity to withdraw water from deep aquifers to supply large quantities of water for industrial and urban water demands, and the ability to supply large quantities of water continuously and safely through organized networks. The application of this method has decreased due to supply management capability reasons (Yannapoulos et al., 2019). In order to reduce the pressure on main water resources in the world and provide water resources in many regions, research on the demand for rainwater harvesting and related issues has accelerated in recent decades (Haque et al., 2016). It is surprising that RWH method is still usable in the modern world, under new socioeconomic conditions and intense environmental pressures that did not exist before, and is even the most suitable method for some regions.

In this article, firstly, the general features and usage examples of RWH technology are included and evaluations are made about whether it is a sustainable water management tool under today's socioeconomic conditions and worsening environmental pressures. Then, the RWH potential in Türkiye was calculated separately for 81 provinces. Using the average rainfall data of the provinces between 1991 and 2020, the amount of rainwater that can be collected from the roofs of the buildings was calculated based on a typical roof area with a surface area of 100 m^2. Two different calculations were made based on this main data. The first was to find out how many days of water needs of one person in each province can be met with the net annual water calculated. The second was to calculate how much water can be saved equivalently from the annual water need if this amount is allocated for the use of a family of 4 people.

Table 2: Falkenmark indicators of river basins (with 2015 data) (Hakyemez, 2019)*

Name of the basin	**Population**	**Usable Water Potential (billio m^3/year)**	**Falkenmark Indicator (m^3/person/year)**	***Class***
Meriç Ergene	749.510	0,76	1014	Water Stress
Marmara	17.608.408	2,84	161,06	Absolute water scarcity
Susurluk	3.793.746	2,57	677,43	Water scarcity
Kuzey Ege	1.112.098	0,88	791,3	Water scarcity
Gediz	1.588.561	0,79	497,31	Absolute water scarcity
Küçük Menderes	4.168.415	0,46	109,15	Absolute water scarcity
Büyük Menderes	1.346.490	1,7	1.262,54	Water Stress
Batı Akdeniz	908.877	3,87	4.258	Water Rich
Antalya	3.341.962	7,03	2.103,55	Water Rich
Burdur	680.105	0,17	244,08	Absolute water scarcity
Akarçay	709.015	0,31	437,23	Absolute water scarcity
Batı Karadeniz	7.262.833	4,03	554,88	Water scarcity
Yeşilırmak	1.879.209	5,09	2.705,93	Water Rich
Kızılırmak	2.721.221	3,1	1.139,19	Water Stress
Konya Kapalı	3.715.291	3,95	1.063,17	Water Stress
Doğu Akdeniz	3.105.368	4,9	1.577,91	Water Stress
Seyhan	1.745.221	4,8	2.747,50	Water Rich
Asi	2.183.167	3,55	1.626,08	Water Stress
Ceyhun	1.533.507	1,18	769,48	Water scarcity
Dicle-Fırat	1.609.483	3,81	2.367,22	Water Rich
Doğu Karadeniz	12.646.409	37,48	2.963,81	Water Rich
Çoruh	2.404.480	9,36	3.892,73	Water Rich
Aras	246.920	4,46	18.064,15	Water Rich
Van Gölü	584.360	3,28	5.609,62	Water Rich
Türkiye (2015)	**1.096.397**	**1,65**	**1.504,93**	**Water Stress**

**The basins in "absolute water scarcity" class are highlighted*

History and General Characteristics of RWH

Archaeological findings regarding the collection and storage of rainwater for domestic and agricultural uses date back to 9000 years ago in Jordan; 6000 years ago, in China; 4500 years ago, in the Sumer region (in modern-day Iraq); in rural Thailand for over 4000 years; B.C. In Israel since 4000 BC; there is evidence that it has been practiced in India since 3000 BC (Mays et. al., 2013; Yannopoulos et al., 2019). In the following period, especially in the Roman period, aqueducts and cisterns became the main feature of a well-designed city. After the collapse of the Roman Empire, there were radical changes in water supply systems. On the other hand, in the eastern part of the Empire, the Roman tradition of construction was preserved for several centuries, mostly applied to irrigation systems in areas of Eastern Mediterranean. During the Byzantine period, many cisterns fed with water carried by aqueducts were built in order to find a solution to the water problem needed by the people as the population increased in Istanbul. Cisterns have been an important part of water supply technology to ensure the sustainability of water resources and the survival and well-being of people. Features such as simplicity, ease of use and not requiring complex controls have brought about the sustainable use of these systems. By the 19th century, distribution cisterns were developed through technological efforts to meet water supply needs with expanding freshwater networks. The gradual application of reinforced concrete has provided the most suitable technique and material for the construction of cisterns or water tanks almost all over the world and has created an international approach in this field, and water supply systems have gradually taken their current form (Mays et. al., 2013).

RWH is the accumulation and storage of rainwater on the surface, underground, in tanks or in the soil for reuse by preventing it from flowing away. Rain harvesting mainly includes methods developed for agricultural, landscaping and household use (Özdemir and Tokuş, 2017). It has become a matter of renewed interest that RWH systems, as a decentralized main or complementary source, are still a sustainable water source for on-site consumption. In this sense, rainwater is suitable for both potable and non-potable uses, allowing the conservation of raw and processed water as well as saving resources (mostly electricity and chemical products) used in water treatment and distribution (Silva et. al., 2022).

Today, impervious layers cover a large area in cities. As seen in Figure 1, as a result of the increase in concrete surfaces and the decrease in green areas, rainwater cannot leak into the ground and is collected from cities through rainwater collection or sewage systems through surface flow. This situation affects the hydrological cycle, reduces rainwater input to groundwater and causes floods. On the other hand, when it rains heavily, rainwater mixed into the sewer line negatively affects the treatment systems (Timur et al., 2012; Özdemir and Tokuş 2017). These issues have led to RWH applications finding application areas all over the world, especially in cities.

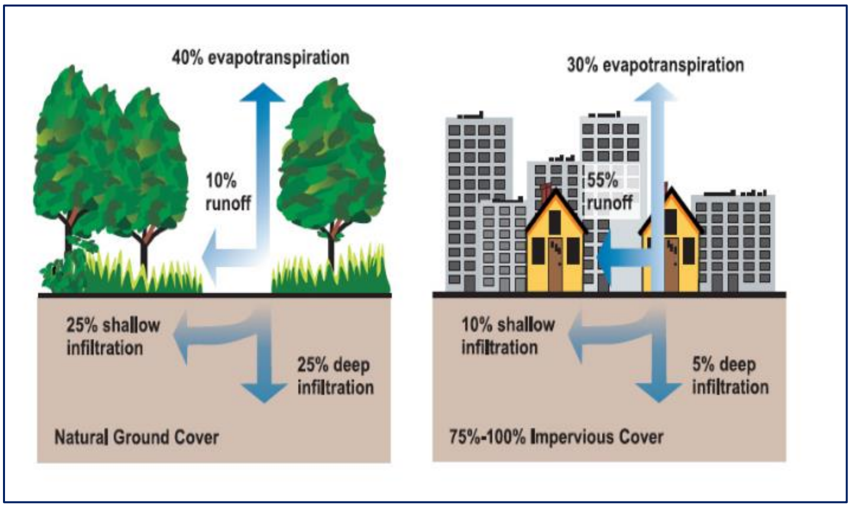

Figure 1: Fate of rainwater in rural areas and cities.
Source: USEPA, 2009

"Water saving" with RWH systems is related to saving water for purposes other than drinking water, and two basic uses of water are increased with these systems: (i) limiting groundwater withdrawal by using collected rainwater, and (ii) performing artificial groundwater replenishment. There are many studies describing the ability of RWH systems to alleviate flooding, provide an additional water source, and even reduce greenhouse gas emissions in urban areas where impervious areas predominate (Gabriela and Vladimir, 2022).

There are basically three areas where rainwater collected in a residential area can be used: use for irrigation purposes as outdoor application, indoor non-potable use, and potable use. These systems generally consist of collection, storage and treatment modules. The main components of this system are filter, water tank, pump, gutter systems and disinfection and treatment techniques depending on the intended use of rainwater (Fewkes, 2005). The components and usage areas of a typical residential type RWH system are given in Figure 2.

The share in the total water consumption provided by the RWH system depends on various factors, such as the quantity and quality of collected rainwater, seasonal variations of precipitation, possible uses of rainwater, water demand, catchment area and tank size. The amount of rainwater that can be captured depends on the rainfall in the field, the flow coefficient and the coefficient of the roof water collection area which is related to its design (), while water quality also depends on the characteristics of the treatment technique used (such as roof type and container size) and site characteristics (e.g., climate, atmospheric pollution and land use) (Dumit Gomez et. al., 2017; Şahin and Manioğlu, 2019; Silva et. al., 2022).

RWH can achieve close to 100% reliability, fully meeting the water demand. This depends on the size of the area where rainwater is collected and the annual precipitation. Therefore, multi-year data of each study region is generally used (Al-Batsh, 2019; Day and Sharma, 2020; Gabriela and Vladimir, 2022), and water balance is made according to water demand and the reliability of the system is determined prior to implementation of the transportation system. It has been determined that in the health emergency caused by COVID-19, rainwater met 94.5% to 238.5% of the water demand for disinfection. However, in regions with strong seasonal variations it may not be possible to meet water demand throughout the year (Van Leeuwen et. al., 2019; Ghodsi et. al., 2023; Gabriela and Vladimir, 2022).

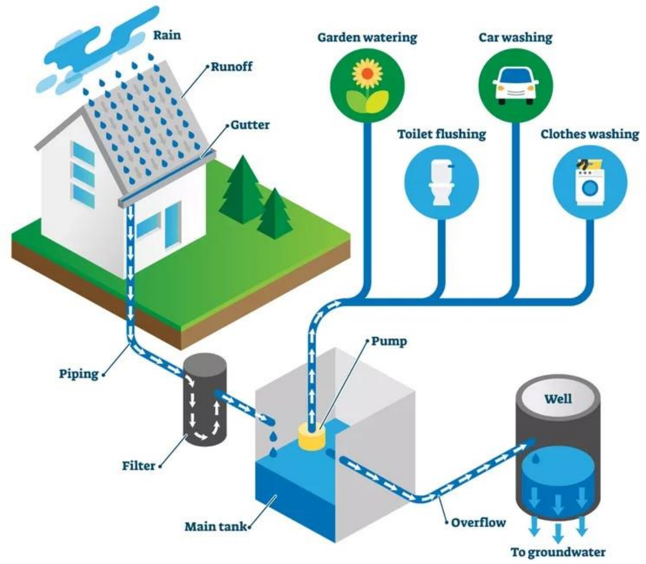

Figure 2: RWH system components.
Source: https://www.istockphoto.com/tr/vekt%C3%B6r/ya%C4%9Fmur-suyu-hasat-sistemi-izometrik-diyagram%C4%B1-gm1201105579-344307644, Rainwater harvesting system isometric diagram.

Waterproof surfaces such as paved areas, roads, parking lots and sidewalks are also considered for RWH. Green areas and pervious soils are also part of the assessment of the amount that can be collected by surface runoff. Awad et al. 2019 evaluated the potential for RWH by surface runoff at a dam between two gently sloping hills. Green roofs (vegetated roofs) can capture and store rainwater, reducing runoff and the risk of flooding (Ranaee et. al., 2021; Zubala and Patro 2021; Gabriela and Vladimir, 2022). Rain gardens can also be given as an example of a RWH system in urban areas. A rain garden is a shallow depression planted with native plants and grasses, ideally replacing an existing lawn. Rainwater from the roof is collected in the existing gutter system, and then directed into depressions created throughout the rain garden. Such systems are maintenance-free substitutes for grasses that are difficult to operate. In this way, it is also guaranteed that the rainwater discharged from the drain pipes is directed in a way that does not endanger the foundation of the building.

RWH APPLICATION EXAMPLES

There are many applications and studies on RWH in the world that are in general about the benefits, design, performance, economic and technical feasibility of RWH systems, and the quality and safety of rainwater. RWH systems are used to manage water supply shortages in developing countries like Bangladesh, Botswana, China, India, Kenya and some other countries in Africa. It is known that RWH has been disseminated throughout Africa and public awareness has been raised by establishing relevant associations in many countries (Campisano et al., 2017). On the other hand, in developed countries such as Germany, France, Japan, Singapore and the USA, rainwater is especially used for garden irrigation, car washing, etc. It is used to support the main water source in different activities (Schets et al., 2010). Rainwater is often used as the main or supplementary water source to the main water supply system in residential buildings. However, it also has extensive applications in other building types such as commercial buildings and public housing in countries such as Japan, England, Australia and Germany (Haque et al., 2016). In some other developed countries, rainwater is also used as drinking water; for example, in Australia rainwater is used as drinking water in some rural and coastal areas where a main water source is not available.

The economic viability of RWH depends on precipitation regime, construction costs and water price. The implementation of RWH systems in various countries of the world is closely related to the price of water. The higher the price, the greater the number of applications and incentives. For example, water is expensive in Germany. Germany leads the way with RWH implementation in Europe, with almost complete water metering and grant-supported RWH systems (EA, 2010). In some parts of Australia, the system has not been found feasible at current water prices (Preeti and Rahman 2021). On the other hand, in some parts of the country, the national water network has been economically feasible in different scenarios compared to bottled water or other water sources (Alim et. al., 2020; Gabriela and Vladimir, 2022). Australia is one of the driest inhabited regions with large variability in rainfall, and it owns the highest prevalence of RWH systems. According to the results of a survey conducted by the Australian Bureau of Statistics, approximately 1.5 million households have installed rainwater tanks in their homes to provide drinking water (Eroksuz and Rahman, 2010).

In a program of the United Nations on the application of RWH systems to reduce sensitivity to climate change in underdeveloped countries, an application was reported in Semarang, one of the cities most affected by climate change in Indonesia. With the RWH system implemented in public schools, 30% of the water used during the rainy season (about six months) could be covered, and more than 20.500 people directly benefited from the common RWH system in a neighbourhood consisting of approximately 40 households near a school (UNFCC, 2024).

Although Brazil bears approximately 18% of the world's total freshwater, only 28% of the country's largest cities have sufficient water. With the program launched in 1999 in the arid region consisting of 9 states in Brazil, which is home to approximately 18 million people, it was aimed to create 1 million houses with rooftop rainwater collection systems, where rainwater can be collected and stored until the dry season to meet the basic drinking water needs of the population living in rural areas. Brazil launched the "One Million Cisterns" program in 2001 and carried out this program to provide water to approximately 2 million people living in rural areas (De Moraes and Rocha, 2013).

Since 2004, it is estimated that the RWH system has been in use in approximately 100.000 residences in different states of the USA. Some states and territories (Hawaii, Kentucky, New Mexico, North Carolina, Ohio, Oregon, Texas, Utah, and Washington) consider RWH a serious practice to protect water resources and increase the volume of available water (USEPA, 2013).

Rainwater storage has been designed in 3 cities with various climatic conditions in Iran. The study conducted in humid, Mediterranean and dry Iranian climates found that at least 75% of residential water demand could be provided by 70%, 40% and 23%, respectively (Mehrabadi et al., 2013). Results from a dry region of Jordan showed that the water saving potential of RWH was between 0.3% and 19.7% (Abdulla and Al-Shareef, 2009; Musayev et. al., 2018).

WATER SAVING POTENTIAL WITH RWH IN TURKIYE

The average annual areal precipitation across Türkiye is 573.4 mm (1991-2020). The areal precipitation in 2023 was 641.5 mm. There was an increase in precipitation of 11.9% compared to normal and 27.3% compared to last year's precipitation (2023). Table 3 shows precipitation variability in Türkiye and its comparison with previous periods. Annual precipitation throughout the country, after being below normal for 3 years, increased above normal in 2023 (GDM, 2024).

Table 3: 2023 areal precipitation comparison in Türkiye (GDM, 2024)

Parameter	**Value**
Precipitation in 2023	641.5 mm
1991-2020 normal	573.4 mm
Precipitation in 2022	503,8 mm
Change from normal	11.9 % (+)
Change compared to 2022	27.3 % (+)

Within the scope of the study, the long-term rainfall average in all 81 provinces in Türkiye, the average precipitation between 1991 and 2020, the amount of precipitation to be collected annually from a 100 m2 roof in each province and how many days of water needs will be met for 1 person this value was calculated with the expression given below:

$$W = \frac{\mathrm{P}\ (\mathrm{L}/m^2)\ \mathrm{x}\ \mathrm{A}\ (m^2)\ \mathrm{x}\ \mathrm{SF}\ (\%)}{\mathrm{C}\ (\frac{\mathrm{L}}{\mathrm{capita.day}})}$$

where:

Average Annual Precipitation (P): This is based on the total annual precipitation recorded between 1991 and 2020 across Türkiye. For example, in Adana, the average annual rainfall is 680.8 mm, which corresponds to 680.80 liters (L) per m2.

Roof Area (A): A typical roof area used is 100 m^2.

Safety Factor (SF): To enhance the accuracy of the calculation, a safety factor of 0.75 is applied. This factor accounts for potential water losses due to issues such as precipitation irregularities, tank fullness, variations in roofing materials, water runoff or bounce-off from the roof, differences in gutter systems, etc. Moreover, in the rainwater efficiency calculation, filter efficiency coefficient and roof coefficient are taken into consideration, as well as the rainwater collection area and rainfall amount. This safety factor of 0.75 serves also for this purpose.

Daily Water Consumption per Person (C): The standard daily water consumption is set at 150 liters (L) per person.

W: Calculated net amount of water

Calculation results for all provinces are included in Table 4.

Table 4: RWH calculation approach in all provinces of Türkiye*

Provinces	**Long-term avg. precipitation (mm)**	**Avg. precipitation 1991-2020 (mm)**	**Amount of water that can be collected from 100 m^2 roof (ton/year)**	**Calculated net amount of water (ton/year)**	**For how many days water can be provided for per person (day)**	**Typical water saving ratio (%)**
Adana	668.2	680.8	68.08	51.06	340	23.64
Adıyaman	**715.1**	**729.5**	**72.95**	**54.71**	**365**	**25.33**
Afyonkarahisar	444.5	451.4	45.14	33.85	226	15.67
Ağrı	523.9	512.9	51.29	38.47	257	17.81
Aksaray	**359.7**	**349.4**	**34.94**	**26.20**	**175**	**12.12**
Amasya	463.8	469.2	46.92	35.19	235	16.29
Ankara	392.4	413.6	41.36	31.02	207	14.36
Antalya	**1053.4**	**1050.0**	**105**	**78.75**	**525**	**36.46**
Ardahan	555.8	600.4	60.04	45.03	300	20.85
Artvin	691.6	724.6	72.46	54.35	362	25.16
Aydın	660.7	653.5	65.35	49.01	327	22.69
Balıkesir	604.5	595.0	59.50	44.63	298	20.66
Bartın	**1058.9**	**1072.4**	**107.24**	**80.43**	**536**	**37.24**
Batman	488.9	493.6	49.36	37.02	247	17.14
Bayburt	449.9	475.6	47.56	35.67	238	16.51
Bilecik	460.6	482.1	48.21	36.16	241	16.74
Bingöl	**947.6**	**935.1**	**93.51**	**70.13**	**468**	**32.47**
Bitlis	**1081.5**	**1046.8**	**104.68**	**78.51**	**523**	**36.35**
Bolu	555.4	573.6	57.36	43.02	287	19.92
Burdur	428.1	432.3	43.23	32.42	216	15.00
Bursa	**708.8**	**719.1**	**71.91**	**59.93**	**400**	**27.75**
Çanakkale	625.3	620.3	62.03	46.52	310	21.54
Çankırı	415.7	427.9	47.79	35.84	239	16.59
Çorum	430.9	448.8	44.88	33.66	224	15.58
Denizli	569.3	573.8	57.38	43.03	287	19.92
Diyarbakır	492.6	498.5	49.85	37.39	249	17.31
Düzce	**837.7**	**822.9**	**82.29**	**61.72**	**411**	**28.57**
Edirne	601.0	625.2	62.52	46.89	313	21.70
Elazığ	420.2	404.0	40.40	30.30	202	14.03
Erzincan	**376.2**	**380.1**	**38.01**	**28.50**	**190**	**13.19**
Erzurum	**431.5**	**395.7**	**39.57**	**29.68**	**198**	**13.74**
Eskişehir	**355.9**	**355.9**	**35.59**	**26.69**	**178**	**12.36**
Gaziantep	564.0	601.6	60.16	45.12	301	20.88
Giresun	**1292.6**	**1308.4**	**130.84**	**98.13**	**654**	**45.43**
Gümüşhane	462.4	465.9	46.59	34.94	233	16.18
Hakkari	**791.9**	**777.3**	**77.73**	**58.30**	**389**	**26.99**
Hatay	**1154.2**	**1124.2**	**112.42**	**84.32**	**562**	**39.03**
Iğdır	**258.4**	**265.8**	**26.58**	**19.94**	**133**	**9.23**
İsparta	567.5	526.3	52.63	39.47	263	18.27
İstanbul	662.5	672.8	67.28	50.46	336	23.36
İzmir	**712.1**	**730.5**	**73.05**	**54.79**	**365**	**25.37**
Kahramanmaraş	721.6	721.6	72.16	54.12	361	25.05
Karabük	487.5	491.7	49.17	36.88	246	17.07
Karaman	**336.7**	**335.3**	**33.53**	**25.15**	**168**	**11.64**
Kars	506.3	527.7	52.77	39.58	264	18.23
Kastamonu	485.1	525.3	52.53	39.40	263	18.24
Kayseri	390.5	408.2	40.82	30.61	204	14.17
Kırıkkale	**385.7**	**386.9**	**38.69**	**29.00**	**193**	**13.42**
Kırklareli	**583.7**	**585.6**	**58.56**	**28.90**	**193**	**13.38**
Kırşehir	**382.6**	**385.4**	**38.54**	**28.91**	**193**	**13.38**
Kilis	499.3	493.4	49.34	37.00	247	17.13
Kocaeli	**816.4**	**850.2**	**85.02**	**63.77**	**425**	**29.52**
Konya	**329.7**	**325.3**	**32.53**	**24.40**	**163**	**11.30**
Kütahya	563.5	550.6	55.06	41.30	275	19.12
Malatya	**383.6**	**365.8**	**36.58**	**27.44**	**183**	**12.70**
Manisa	743.6	724.6	72.46	54.35	362	25.16
Mardin	673.5	610.1	61.01	45.76	305	21.19
Mersin	610.9	610.9	61.09	45.82	305	20.93
Muğla	**1206.1**	**1165.2**	**116.52**	**87.39**	**583**	**40.46**
Muş	**759.6**	**781.9**	**78.19**	**58.64**	**391**	**27.15**
Nevşehir	422.2	418.0	41.80	30.81	205	14.26
Niğde	**343.0**	**349.9**	**34.99**	**26.24**	**175**	**12.15**

Provinces	Long-term avg. precipitation (mm)	Avg. precipitation 1991-2020 (mm)	Amount of water that can be collected from 100 m^2 roof (ton/year)	Calculated net amount of water (ton/year)	For how many days water can be provided for per person (day)	Typical water saving ratio (%)
Ordu	**1051.7**	**1066.0**	**106.60**	**79.95**	**533**	**37.01**
Osmaniye	**816.8**	**839.8**	**83.98**	**62.99**	**420**	**29.16**
Rize	**2300.0**	**2309.5**	**230.95**	**173.21**	**1155**	**80.19**
Sakarya	**846.0**	**878.6**	**87.86**	**65.90**	**439**	**30.51**
Samsun	**723.2**	**729.7**	**72.97**	**54.73**	**365**	**25.34**
Siirt	716.0	700.7	70.07	52.55	350	24.33
Sinop	691.4	727.8	72.78	54.59	364	25.27
Sivas	431.1	455.4	45.54	34.16	228	15.81
Şanlıurfa	460.4	450.5	45.05	33.79	225	15.64
Şırnak	**712.4**	**768.3**	**76.83**	**57.62**	**384**	**26.68**
Tekirdağ	580.0	601.1	60.11	45.08	301	20.87
Tokat	435.0	442.9	44.29	33.21	221	15.38
Trabzon	**828.9**	**902.1**	**90.21**	**67.66**	**451**	**31.32**
Tunceli	**873.0**	**826.6**	**82.66**	**61.70**	**411**	**28.56**
Uşak	557.6	564.5	56.45	42.34	282	19.60
Van	393.2	410.2	41.02	30.77	205	14.25
Yalova	**755.9**	**748.9**	**74.89**	**56.17**	**375**	**26.00**
Yozgat	571.4	595.7	59.57	44.68	298	20.69
Zonguldak	**1228.1**	**1238.6**	**123.86**	**92.90**	**619**	**43.00**

*In the provinces marked in blue, the water needs of one person for can be met with RWH more than 1 year (365 days).
*In the provinces marked in orange, the water needs of one person can be met with RWH for less than 7 months (200 days).

As can be seen from Table 4, it is understood that in 22 provinces, the water needs of one person for more than 1 year (365 days) can be met with annual RWH, while in 12 provinces, on the contrary, the water needs of less than 7 months in 1 year can be met. In the other 47 provinces, this affordability period varies between 200-365 days. This indicates that our country consists of various climatic regions.

Figure 3 shows the climate zones map of Türkiye. As can be seen from the map, in our country, which is surrounded by seas on three sides; Black Sea, Mediterranean and Marmara climates prevail in the coastal areas, while in the continental climate zone there are Eastern Anatolia, Central Anatolia, South-eastern Anatolia and Thrace climate zones. Due to this diversity, the amount of precipitation that can be collected varies from province to province

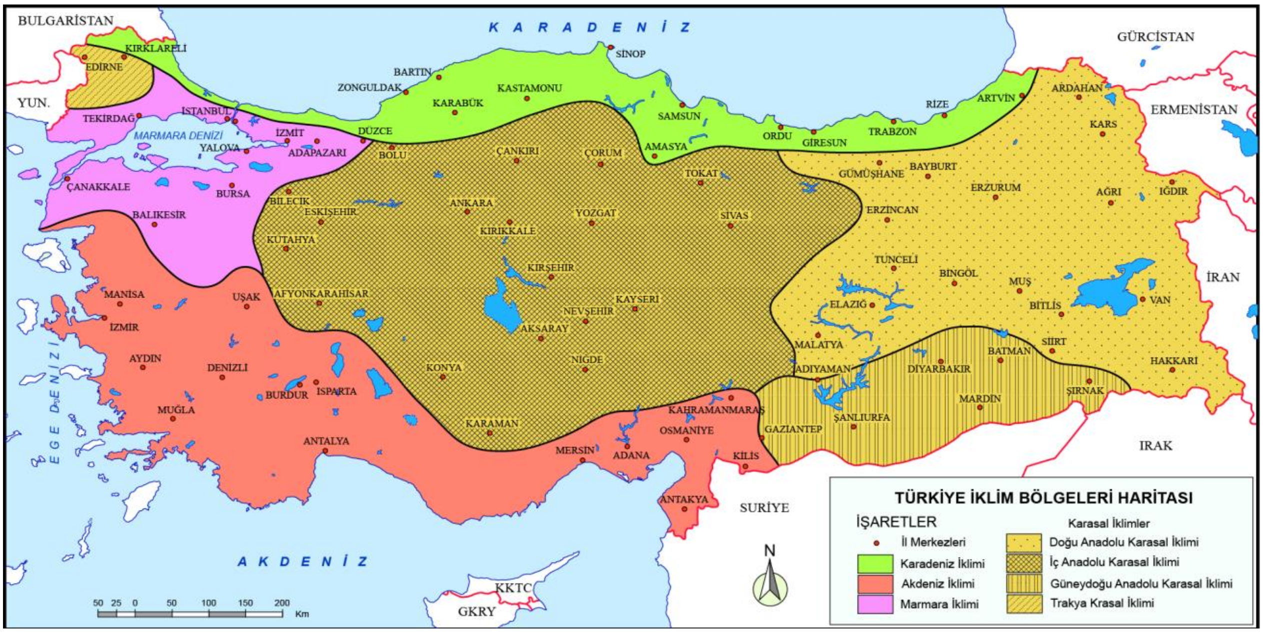

Figure 3: Map of Türkiye's climate zones
Source: http://cografyaharita.com/haritalarim/2cturkiye-iklim-tipleri-haritasi.png

In the analysis made on a provincial basis, it was revealed that each province varies depending on the amount of precipitation that can be collected. However, considering the investment and operating expenses of RWH systems, payback periods vary depending on different building typologies, but periods around 10 years are acceptable (RWH Guidelines, 2022). Saving rates can also be found through another analysis of water savings regarding net water amounts calculated on provincial basis. Thus, while household water payments decrease in proportion to savings, the same amount of savings will also help to protect natural water resources. In this context, a typical calculation can be made. If RWH is constructed from a 100 m2 roof area of a detached house where 4 people live, the water saving rate of the family living in Adana can be easily found.

4 persons x 150 L/person/day x 30 days/month x 12 months/year= 216 m3/year water demand

Net amount of water obtained by RWH = 51,06 m3/year (from Table 4)

Annual water saving rate = 23.64%

Daily domestic water need of a human is taken as 150 L/day. However, it must be kept in mind that part of this water requires high quality especially for drinking, cooking, bathing which cannot be substituted with rainwater that has not undergone any treatment including disinfection. The rest of water consumption does not necessarily need to be of high quality and can easily be coupled with rainwater like cleaning, flushing, garden irrigation and laundry. To keep the results more understandable for readers and to compare the situation of different provinces, a fixed value of 150 L/person/day is simply used in the calculations.

By following the same steps, the annual water saving rate in each province can be designed. In Table 4, annual water saving rates of each province are given in the rightmost column. In our country, which has many different climate zones, the savings rate varies between 9.23-80.19%. While the saving rate is between 26-80% in 22 provinces where one person's water needs for more than 1 year (365 days) can be met with the RWH collected in 1 year, in 12 provinces where the water needs of less than 7 months in 1 year can be met, this rate varies between 9.23-13.74%. Such a situation shows that water saving is possible even in provinces with the least rainfall. In fact, there is a much higher potential for savings in provinces with relatively high precipitation.

Studies are being carried out in many parts of the world on water saving rates that can be achieved with RWH. Some examples of these are given in Table 5 (Silva et. al., 2022) and data on water saving rates are shared. When a simple study conducted in the provinces of Turkey is compared with world examples, it is seen that the water saving rates to be achieved with RWH vary depending on the rainfall status of the relevant region. Many studies also indicate that these wide range values depend on many factors.

Table 5. Water saving rates by RWH applications (Silva et. al., 2022)

RWH Application areas	Water savings (%)	Reference
12 cities in Jordan	0-20	Abdulla and Al-Shareef (2009)
22 cities in Egypt	0-12	Gado and El-Agha (2020)
Residences in Germany	30-60	Hermann and Schmida (2000)
195 cities in Southeast Region of Brazil	12-79	Ghisi et al. (2007)
Residents in Sant Cugat del Valles, Spain	16	Domenech and Sauri (2011)
Low-income homes in Florianopolis, Brazil	22-64	Vieira and Ghisi (2016)
Four-story residential building composed of 3 blocks in Florianopolis, Brazil	15-18	Ghisi and Ferreira (2007)

CONCLUSION

Since one of the important goals of sustainable water management is to encourage effective and efficient water use, this study reveals that the amount of water that can be obtained with RWH in Türkiye is an undeniable amount. In addition to the environmental and economic importance of the issue, its social dimension should also be considered. In this context, it should be emphasized in every segment of society that water is indispensable for life, public awareness should be raised, and activities that will raise awareness and conscious water use in every water-dependent sector, especially agriculture, should be accelerated. Otherwise, already limited water resources will decrease even further as a result of the negative effects of climate change on water resources. It should not be forgotten that since the need for water will increase in parallel with the increase in population, we will face serious water problems in the near future if precautions are not taken.

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